

# Gaugino Mass dependence of Electron and Neutron Electric Dipole Moments

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February 1, 2008

## Abstract

Unless squarks and sleptons are in the multi-TeV region or above, CP violating induced electric dipole moments of elementary particles can pose significant puzzles for supersymmetric (SUSY) models. We study the dipole-moment-inducing one-loop amplitudes as a function of the fundamental SUSY parameters and show that these puzzles are removed if there is a sufficiently large hierarchy between the gaugino masses and the scalar mass. We comment on the experimental status of the low gaugino mass scenario.

## 1 Introduction

It is well known that the standard model by itself does not provide a sufficiently strong source of CP violation to ensure baryogenesis assuming an initially matter-antimatter symmetric universe. From this point of view, the extra sources of CP violation natural in a

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supersymmetric (SUSY) theory are welcome additions to the theory. In SUSY the Higgs mixing parameter  $\mu$  in the superpotential and the soft SUSY breaking Majorana gaugino masses and trilinear couplings generically contain CP violating phases. These can be written

$$\mathcal{L}_{soft} = \frac{1}{2} M_a \lambda_a \lambda_a - \epsilon_{jk} \left( h_2^j \tilde{u}_R^\star A_u \tilde{q}_L^k - h_1^j \tilde{e}_R^\star A_\ell \tilde{\ell}_L^k - h_1^j \tilde{d}_R^\star A_d \tilde{q}_L^k \right) + h.c. + \dots . \quad (1.1)$$

There is no known mechanism, once SUSY breaking is introduced, to have the phases in the gaugino masses  $M_a$ , the Higgs mixing parameter  $\mu$ , or the trilinear couplings  $A$  anomalously small and indeed, from the point of view of baryogenesis, one might hope that these phases are near maximal. On the other hand, the precision limits [1] on electron and neutron electric dipole moments (EDM's) then pose significant problems for SUSY:

$$|d^e| \leq 2.15 \cdot 10^{-13} e/GeV \quad (1.2)$$

$$|d^N| \leq 5.5 \cdot 10^{-12} e/GeV \quad (1.3)$$

It is known [2, 3, 4, 5] that, if all SUSY particles are near some common scale  $m_0$ , induced electric dipole moments greatly exceed the experimental limits unless a)  $m_0$  is of order several TeV, b) the naturally occurring SUSY phases are extremely small, or c) highly fine-tuned relationships exist between the SUSY phases and the other parameters of the theory (masses and coupling constants). Each of these is problematic for the theory from the point of view of naturalness, radiative breaking of the electroweak symmetry and baryogenesis [6]. For a review see [7]. A compromise combining aspects of all three of these solutions is also not totally satisfactory and it is still interesting to ask whether there is an alternative solution which preserves the possibility of SUSY breaking near the 100 GeV scale and possible maximal CP violations in other processes.

In the Lagrangian one of the complex fermion mass parameters  $M_{1,2,3}$  and  $\mu$  can be made real by a phase transformation of the fermion fields, shifting the phase to the other parameters. Thus, it is clear that if the gaugino masses and the  $A$  parameters go to zero, the theory becomes CP conserving independent of the value of the  $\mu$  parameter. In this article we investigate how small the gaugino masses must be to respect the experimental limits on the dipole moments for low values of the scalar masses.

Such a hierarchy can be naturally obtained by imposing on the Lagrangian an approximate R symmetry which then guarantees vanishing gaugino masses and  $A$  parameters at tree level. This corresponds to the scenario in which gluino and photino masses are very light and the other gauginos are in the W,Z mass region. Although direct searches for light gluinos have been negative up to now and some experimental counterindications have been presented, the scenario is still not conclusively ruled out. The opposite scenario in which gaugino masses are orders of magnitude above the scalar masses is another possibility which can solve the dipole moment problem while still leaving squarks and sleptons at the 100 GeV scale. It is, however, not clear whether this can be done in a natural way.

The structure of the paper is as follows. In section II we discuss the gluino contributions to the quark electric dipole moments and present the excluded regions in the  $m_0, M_3$  plane if this contribution is to separately respect the experimental limits on the Neutron dipole moment with maximum CP violating phase. In this paper, unless otherwise specified,  $m_0$  and  $A$  are the scalar mass and trilinear coupling appropriate to the first generation only. In section III, we discuss the corresponding limits in the  $m_0, M_2$  plane assuming the chargino contribution to the electron EDM is similarly consistent with experiment. The results of sections II and III show that the EDM's go to zero if  $M_2$  and  $M_3$  tend to zero (or infinity) for fixed scalar masses.

In section IV we analyze the more complicated neutralino contributions and show that these also vanish if the tree level gaugino masses (together with the  $A$  parameter) tend to zero even though the physical gaugino mass eigenstates are then of order  $M_W^2$ .

In section V we discuss the current viability of the low gaugino mass scenario and other alternative solutions suggested by the present work.

## 2 Gluino Contributions to Quark Diple Moments

The simplest SUSY contribution to the electric dipole moments is that of the gluino. It can be written [2]

$$d_{\tilde{g}}^q = -\frac{2em_q\alpha_s Q_q}{3\pi(\tilde{m}_1^2 - \tilde{m}_2^2)} \text{Im} \left( M_3(\mu\Theta(\beta) - A_q^*) \right) \sum_{k=1}^2 \frac{(-1)^k}{\tilde{m}_k^2} B(M_3^2/\tilde{m}_k^2) \quad (2.1)$$

Here  $\tilde{m}_k$  is the mass of the  $k$ 'th scalar partner of the quark  $q$ , with  $\tilde{m}_1$  being the lighter of the two. We have neglected terms higher than first order in the quark mass  $m_q$ .  $\Theta(\beta)$  is  $(\tan\beta)^{(-2T_3)}$  for a quark of weak isospin  $T_3$ . For large  $\tan\beta$  the dipole moment of the down quark becomes greater, exacerbating the dipole moment problem. We therefore assume  $1.2 < \tan\beta < 3$ . The  $B$  function is

$$B(r) = \frac{1}{2} + rA(r) \quad (2.2)$$

with

$$A(r) = \frac{\ln r}{(1-r)^3} + \frac{3-r}{2(1-r)^2} \quad (2.3)$$

Note that  $r^{(1/2)}B(r)$  has an inversion symmetry.

$$r^{1/2}B(r) = r^{-1/2}B(r^{-1}) \quad (2.4)$$

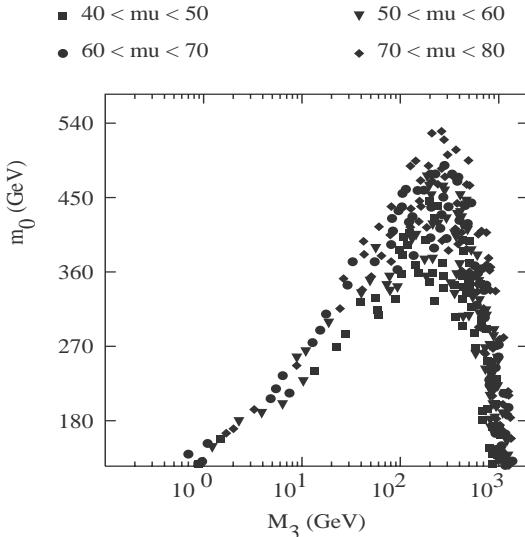


Figure 1: Minimum values of scalar mass,  $m_0$ , as a function of the SU(3) gaugino mass,  $M_3$ , for various indicated values of  $\mu$  and for  $\tan\beta$  between 1.2 and 3.0 assuming the CP violating phase angle is between 0.95 and 1.0.

It is clear, therefore, that the gluino contribution to the quark (and consequently to the neutron) electric dipole moment vanishes if the gluino mass  $M_3$  becomes sufficiently small or sufficiently large for any fixed squark mass. In actuality, the gluino contribution is not very constraining for SUSY. In fig. 1, the shape coded points are values in the  $M_3 - m_0$  plane in which the gluino contribution to the down quark dipole moment saturates the experimental limit on the neutron dipole moment for values of  $\tan\beta$  between 1.2 and 3 and for indicated values of  $\mu$ . The chosen values of  $\mu$  are those which are most likely to allow viable tree level physical chargino and neutralino masses in the low gaugino mass limit. Regions in the plane above the arched curve are consistent with maximum CP violating phases and regions below the curve are experimentally excluded. If the universal scalar mass  $m_0$  is above the relatively low value of 350 GeV, the gluino contribution to the quark dipole moments does not exceed the limit on the neutron EDM as can be seen from fig. 1. On the other hand, if the scalar mass  $m_0$  is in the region of current experimentation ( $\approx 100$  GeV), the gluino mass must be either below 1 GeV or above 1 TeV assuming, as before, maximal CP violating phases.

### 3 Chargino Contributions to the electron EDM

In the presence of CP violating phases, a chargino-sneutrino loop induces an EDM in the electron. In minimal SUSY, the chargino is a mixture of Wino and charged Higgsino. The tree level mass matrix is

$$M_{\chi^+} = \begin{pmatrix} M_2 & \sqrt{2}M_W \sin \beta \\ \sqrt{2}M_W \cos \beta & \mu \end{pmatrix} \quad (3.1)$$

As shown in [2], the chargino contribution to the electron EDM is

$$d_{\chi^\pm}^e = \frac{-e\alpha m_e}{4\pi\sqrt{2}M_W \cos(\beta)\sin \theta_W^2} \sum_{j=1}^2 \text{Im}(U_{j2}V_{j1}) \frac{m_{\chi_j}}{m_{\tilde{\nu}}^2} A\left(m_{\chi_j}^2/m_{\tilde{\nu}}^2\right) \quad (3.2)$$

The  $A$  function, not to be confused with the trilinear  $A$  parameter, is given by Eq.2.3.

$U$  and  $V$  are the bi-unitary matrices that relate the tree level mass matrix,  $M_{\chi^+}$ , to the masses of the chargino eigenstates,  $m_{\chi_j}$ .

$$\sum_j U_{j\alpha} m_{\chi_j}^{2n+1} V_{j\beta} = \left[ M_{\chi^+} \left( M_{\chi^+}^\dagger M_{\chi^+} \right)^n \right]_{\alpha\beta} \quad (3.3)$$

Thus

$$d_{\chi^\pm}^e = \frac{-e\alpha m_e}{4\pi\sqrt{2}M_W \cos \beta \sin \theta_W^2 m_{\tilde{\nu}}^2} \text{Im} \left[ M_{\chi^+} A \left( M_{\chi^+}^\dagger M_{\chi^+} / m_{\tilde{\nu}}^2 \right) \right]_{21} \quad (3.4)$$

By explicit consideration of the general form of the two-by-two matrices,  $U$  and  $V$ , one can show that

$$d_{\chi^\pm}^e = \frac{-e\alpha m_e \tan \beta}{4\pi \sin \theta_W^2 m_{\tilde{\nu}}^2 (m_{\chi_+}^2 - m_{\chi_-}^2)} \left[ A \left( m_{\chi_+}^2 / m_{\tilde{\nu}}^2 \right) - A \left( m_{\chi_-}^2 / m_{\tilde{\nu}}^2 \right) \right] \quad (3.5)$$

The mass eigenstates, obtained by diagonalizing  $M_{\chi^+}^\dagger M_{\chi^+}$ , are such that

$$m_{\chi_\pm}^2 = M_W^2 + |\mu|^2/2 + |M_2|^2/2 \pm \left[ \left( M_W^2 + |\mu|^2/2 + |M_2|^2/2 \right)^2 - |M_W^2 \sin 2\beta - M_2 \mu|^2 \right]^{1/2} \quad (3.6)$$

The properties of the  $A$  function are such that the chargino contribution to the electron EDM vanishes as  $M_2$  goes to zero or infinity for any fixed mass of the scalar neutrino although this behavior is not obvious from eq.3.2 since for  $M_2$  going to zero the chargino masses are in the  $W$  mass region. Thus, assuming maximum CP violating phase, the chargino contribution to the electron EDM, by itself, satisfies the experimental bound for values of the scalar mass  $m_0$  above the curves of fig. 2. The chargino contribution is seen to be quite restrictive for the theory. For scalar masses in the region of current experimentation ( $\approx 100$  GeV), five orders of magnitude in the  $SU(2)$  gaugino mass are experimentally excluded for maximum phase. For  $M_2$  in the 100 GeV region, as is often assumed, the scalar mass would have to

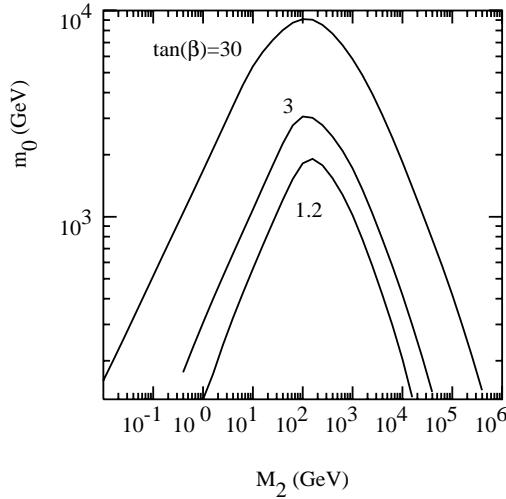


Figure 2: Minimum values of scalar mass,  $m_0$ , as a function of the SU(2) gaugino mass,  $M_2$ , for various indicated values of  $\tan\beta$ . Here  $\mu = 50$  GeV and the CP violating phase between  $\mu$  and  $M_2^*$  is taken to be  $\phi = 45$  deg.

be above 1 TeV leading to severe problems for the hypothesis of radiative breaking of the electroweak symmetry.

With  $M_2$  sufficiently small (or sufficiently large) to satisfy the dipole moment bounds, gaugino mass universality would exclude a wider range of gluino masses than could be directly excluded by the gluino contribution to the neutron EDM considered in the previous section.

If the chargino contribution to the electron EDM is, by itself, consistent with the experimental limit, it will pose no problem for the neutron EDM since, even though the fermion mass is then an order of magnitude greater, the experimental limit is almost two orders of magnitude weaker.

## 4 Neutralino Contributions to the electron EDM

Finally we turn to the neutralino contribution to the electron EDM. In this case we cannot, in general, find a closed form expression analogous to eq.3.5 since the neutralino system is a mixture of four states. With basis states  $\tilde{\gamma}, \tilde{Z}, \tilde{H}_1, \tilde{H}_2$ , the tree level mass matrix is given by

$$M_{\chi^0} = \begin{pmatrix} M_2 s^2 + M_1 c^2 & (M_2 - M_1)sc & 0 & 0 \\ (M_2 - M_1)sc & M_2 c^2 + M_1 s^2 & M_Z & 0 \\ 0 & M_Z & \mu \sin 2\beta & -\mu \cos 2\beta \\ 0 & 0 & -\mu \cos 2\beta & -\mu \sin 2\beta \end{pmatrix} \quad (4.1)$$

Here  $s$  and  $c$  are the sin and cos respectively of the weak angle. With  $\mu$ ,  $M_1$  and  $M_2$  in general complex, the matrix is non-Hermitian and the mass eigenstates are found by diagonalizing  $M_{\chi^0}^\dagger M_{\chi^0}$ .

In [2], the contribution to the electron EDM is given in terms of the physical neutralino masses,  $m_{\chi_k^0}$ , and mixing matrices,  $N_{jk}$ . Neglecting terms higher order in the electron mass this can be written

$$d_{\chi^0}^e = \frac{-Q\alpha m_e}{8\pi s^2 c^2} \sum_{m=1}^2 \frac{1}{\tilde{m}_m^2} \sum_{i=1}^2 \sum_{j=1}^4 \sum_{k=1}^4 \text{Im} \left[ N_{ik}^* N_{jk}^* \gamma_{ij} \right] m_{\chi_k^0} B \left( m_{\chi_k^0}^2 / \tilde{m}_m^2 \right) \quad (4.2)$$

Here  $\tilde{m}_m$  is the mass of the  $m$ th selectron and the coefficients  $\gamma_{ij}$  are

$$\gamma_{ij} = a_j \left( b_i (-1)^m \left( \frac{\mu \Theta(\beta) - A^*}{\tilde{m}_1^2 - \tilde{m}_2^2} (\delta_{j1} + \delta_{j2}) + (\delta_{j3} + \delta_{j4}) / M_Z \right) + \delta_{i2} \delta_{m1} (\delta_{j3} + \delta_{j4}) / M_Z \right) \quad (4.3)$$

The coefficients  $a_i$  and  $b_i$  are given by

$$\begin{aligned} a_1 &= -Q \sin(2\theta_W) \\ a_2 &= -1 + 2Q \sin(2\theta_W)^2 \\ a_3 &= 2T_3 \\ a_4 &= -\Theta(\beta) \\ b_i &= -a_i + \delta_{i2} \end{aligned} \quad (4.4)$$

For the electron,  $T_3 = -1/2$  and  $\Theta(\beta) = \tan \beta$ . The unitary matrix  $N$  relates the neutralino mass matrix,  $M_{\chi^0}$  to the physical masses

$$\sum_{k=1}^4 N_{\alpha k}^* m_k^{2n+1} N_{\beta k}^* = \left[ M_{\chi^0} \left( M_{\chi^0}^\dagger M_{\chi^0} \right)^n \right]_{\alpha\beta} \quad (4.5)$$

We can thus write the relation between the electron EDM and the tree level mass matrix

$$d_{\chi^0}^e = \frac{-Q\alpha m_e}{8\pi s^2 c^2} \sum_{i=1}^2 \sum_{j=1}^4 \text{Im} \gamma_{ij} \left[ M_{\chi^0} B \left( M_{\chi^0}^\dagger M_{\chi^0} / \tilde{m}_m^2 \right) \right]_{ij} \quad (4.6)$$

It is now easy to show that the neutralino contribution to the EDM vanishes as  $M_1, M_2$ , and the trilinear coupling  $A$  go to zero. It is clear from eq.4.6 that the EDM is proportional to elements from the first two rows of the neutralino mass matrix  $M_{\chi^0}$ . Of these only the

23 element survives as  $M_1$  and  $M_2$  go to zero. In the limit of vanishing gaugino masses the dipole moment, therefore, becomes

$$d_{\chi^0}^e = \frac{-Q\alpha m_e M_Z}{8\pi s^2 c^2} \sum_{m=1}^2 \frac{1}{\tilde{m}_m^2} \sum_{j=1}^4 \text{Im} \left[ \gamma_{2j} B \left( M_{\chi^0}^\dagger M_{\chi^0} / \tilde{m}_m^2 \right)_{3j} \right] \quad (4.7)$$

$\gamma_{2j}$  is real for  $j = 3$  or  $4$ . Since  $B$  is Hermitian,  $B_{33}$  is real. As  $M_1$  and  $M_2$  go to zero,  $(M_{\chi^0})_{k1} \rightarrow 0$  and therefore  $B_{31} \rightarrow 0$ . The remaining terms in the sum on  $j$  are then

$$d_{\chi^0}^e = \frac{-Q\alpha m_e M_Z}{8\pi s^2 c^2} \sum_{m=1}^2 \frac{1}{\tilde{m}_m^2} \text{Im} \left[ \gamma_{22} B \left( M_{\chi^0}^\dagger M_{\chi^0} / \tilde{m}_m^2 \right)_{32} + \gamma_{24} B \left( M_{\chi^0}^\dagger M_{\chi^0} / \tilde{m}_m^2 \right)_{34} \right] \quad (4.8)$$

With  $M_1$  and  $M_2$  going to zero, the only off-diagonal terms in  $M_{\chi^0}^\dagger M_{\chi^0}$  are

$$(M_{\chi^0}^\dagger M_{\chi^0})_{32} = M_Z \mu^* \sin(2\beta) \quad (4.9)$$

$$(M_{\chi^0}^\dagger M_{\chi^0})_{24} = -M_Z \mu \cos(2\beta) \quad (4.10)$$

together with their conjugate elements. Thus

$$B_{32} = (M_{\chi^0}^\dagger M_{\chi^0})_{32} \cdot \text{real} = \mu^* \cdot \text{real} \quad (4.11)$$

$$B_{34} = (M_{\chi^0}^\dagger M_{\chi^0})_{32} (M_{\chi^0}^\dagger M_{\chi^0})_{24} \cdot \text{real} = \text{real} \quad (4.12)$$

Using the explicit form of  $\gamma_{ij}$ , it is then clear that the dipole moment vanishes for vanishing gaugino masses,  $M_1$  and  $M_2$ , providing the  $A$  parameter also vanishes (or has opposite phase to  $\mu$ ). The gaugino masses and the  $A$  parameter vanish in a technically natural way if one imposes a continuous  $R$  symmetry on the Lagrangian although we must still discuss in the next section whether this is a phenomenologically viable possibility.

To numerically evaluate eq.4.6 we expand the  $B$  functions in inverse powers of the selectron masses,  $\tilde{m}_m$ . For simplicity we put  $M_2 = 0$  since this gaugino mass is strongly constrained by the chargino contribution. We keep terms up to order  $\tilde{m}_m^{-6}$ .

If we consider the matrix argument

$$r = M_{\chi^0}^\dagger M_{\chi^0} / \tilde{m}^2 \quad (4.13)$$

one can show that

$$A(r)_{jk} = \delta_{jk} A(r_{kk}) - (1 - \delta_{jk}) r_{jk} \frac{A(r_{jj}) - A(r_{kk})}{r_{jj} - r_{kk}} + \mathcal{O}(\tilde{m}^{-4}) \quad (4.14)$$

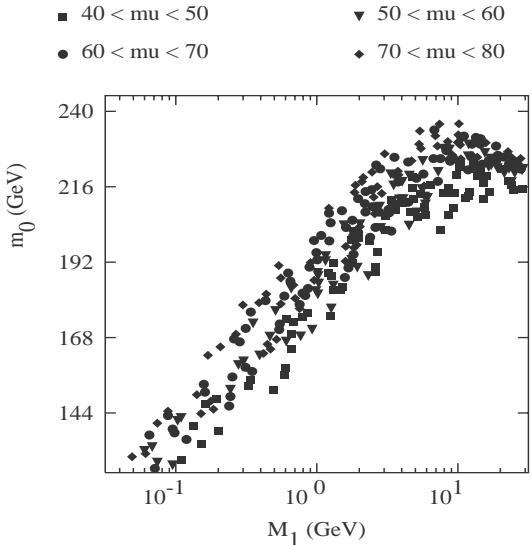


Figure 3: Minimum values of scalar mass,  $m_0$ , as a function of the U(1) gaugino mass,  $M_1$ , for various indicated values of  $\mu$  and for  $\tan\beta$  between 1.2 and 3.0 assuming the CP violating phase angle is between 0.95 and 1.0.

The result, which of course is only valid for small  $M_1/\tilde{m}_m$ , is shown in Fig. 3. Over the region plotted in Fig. 3, the  $(1 - \delta_{jk})$  terms in Eq. 4.14 gives a small ( $\mathcal{O}(10\%)$ ) contribution. We expect however that, using the inversion symmetry of the B function, one should be able to show that the dipole moment contribution will also become small for large gaugino masses at fixed scalar mass. We have checked numerically that this decoupling holds.

As in the case of the gluino contribution, the neutralino contribution is sufficiently small once the scalar mass is above several hundred GeV. However, if the squarks and sleptons are in the region of current experimentation near 100 GeV, very small (or perhaps very large) gaugino masses are required if the CP violating phase is near maximum and there are no special cancellations.

## 5 Status of the low gaugino mass scenario

In the supergravity mediated SUSY breaking scheme, the three gaugino masses,  $M_1$ ,  $M_2$ , and  $M_3$  are expected to be equal at the unification scale and approximately proportional to the corresponding gauge couplings at low energies. However, in more general schemes, the gaugino masses could widely differ. Since the early days of SUSY there has been much discussion of the aesthetics and viability of a light gluino ( $M_3 \approx 0$ ) [8]. The primary indication of a light gluino would be an anomalously slow running of the strong coupling constant. In the last decade there were in fact several indications that this was, in fact, the case

[9, 10, 11, 12, 13]. More recent re-analyses of deep-inelastic data and lattice gauge calculations, together with the widespread feeling that the  $\tau$  decay width is the best low energy measure of  $\alpha_s$ , have significantly weakened the case for an anomalously slow running. There remain, however, persistent anomalies especially in the quarkonia decay rates [14] requiring an assumption of extremely large and negative relativistic corrections to the wave functions to obtain consistency with the standard model. LEP measurements of the running of  $\alpha_s$  in the LEP II region seem, also, to be consistent with the standard model. However, in view of the relatively poor statistics above the  $Z$  together with systematic problems associated with radiative return events,  $W$  pair production etc. and in view of the anomalously large jet production rates observed at Fermilab and perhaps HERA at high scales, the case for a standard model running in the high energy region cannot be considered absolutely settled. Several features of the Fermilab jet data and top quark candidates seem, in fact, in line with what one would expect in the light gluino scenario [15, 16] with, perhaps valence squarks in the 100 GeV region.

Counterindications to a very light gluino have been published coming from the four-jet angular distributions [17], and from direct searches [18, 19]. The four-jet results, which suggest a gluino mass of at least 6.3 GeV, are, however, subject to criticism [20], and it is possible that systematic errors related to monte-carlo dependence might be underestimated. The negative result from *E761* could be consistent with a light gluino if  $qq\tilde{g}$  and  $q\bar{q}\tilde{g}$  bound states are not formed for the same reason that no strong candidates exist for the hybrid states of quarks and gluons  $qqqg$  and  $q\bar{q}g$ . Presumably, the QCD potential is too repulsive in the requisite color octet sub-states. Similarly the KTeV result would not strongly impact the light gluino hypothesis if the  $R^0(g\tilde{g})$  state is too long lived as might occur if the photino were not sufficiently lighter in mass or in some gauge mediated SUSY breaking schemes.

If the gluino is light (below 10 GeV) it is expected that the charginos and neutralinos would have dominantly non-leptonic decay modes into quark-antiquark-gluino. Thus the traditional signatures for these particles, isolated leptons and/or significant missing energy, would be invalidated. A dedicated search involving hadronic decay channels would then be required. As yet only the OPAL experiment has published the results of such a dedicated search [21]. The graph in this reference constraining the chargino mass is, however, fully consistent with vanishing  $M_1$  and  $M_2$ . The resulting parameters,  $\mu$  and  $\tan\beta$ , however, are said to be inconsistent with the neutralino search if  $M_1$  is zero. The OPAL work suggests that, assuming a light gluino decay of the charginos and neutralinos, the origin in the  $M_1 - M_2$  plane is excluded. Even this result is in question since they assumed a 100% hadronic decay which is unlikely even if the hadronic modes dominate. An extension of the OPAL analysis to exclude a finite region in the  $M_1 - M_2$  plane is highly desirable. With  $M_1 = M_2 = 0$ , the lightest chargino should be between 50 and 70 GeV at tree level but this mass might be increased somewhat by one-loop corrections. It would be useful if the LEP experiments other than OPAL would also publish results on hadronic events in the 100 to 180 GeV region. Since this overlaps the  $W$  pair production region, it would be important to know whether there is sufficient flexibility in the Monte Carlos to allow the existence of such charginos in

addition to whether the data is consistent with the standard model.

We would also like to comment on the value of  $\tan\beta$ , which in our scenario is  $1.2 < \tan\beta < 2$ . It strongly determines the Higgs mass. In our scenario one would get within the MSSM a mass of  $h^0$  between 61.3 GeV (for  $\tan\beta = 1.2$ ) and 77.3 GeV (for  $\tan\beta = 2$ ) for  $m_A = 200$  GeV, and the SUSY breaking parameters  $A = 0$ ,  $M_{Q_3} = 500$  GeV,  $M_{U_3} = 450$  GeV,  $M_{D_3} = 500$  GeV. (The mass scale of the sfermions of the first and second generation is unimportant). The present experimental bound on the mass of  $h^0$ ,  $m_h \geq 110$  GeV for  $\tan\beta < 3$ , however, strongly relies on the dominance of the decay  $h^0 \rightarrow b\bar{b}$ . In our case the branching ratio of this decay can be substantially reduced due to the possible decay modes  $h^0 \rightarrow \tilde{g}\tilde{g}$  [22] and  $h^0 \rightarrow \tilde{\chi}_2^0\tilde{\chi}_2^0$  with  $\tilde{\chi}_2^0 \rightarrow q\bar{q}\tilde{g}$ . A flavour independent search for a neutral scalar Higgs was performed by OPAL[23]. According to this study, a Higgs mass  $< 66.2$  GeV, is excluded for  $\sin^2(\beta - \alpha) \geq 0.5$ , where  $g \sin(\beta - \alpha)/\cos\theta_W$  is the coupling to  $Z^0$ . Hence a Higgs mass corresponding to our scenario is still possible especially if the coupling to the  $Z^0$  is suppressed. In this context we would also like to mention the next-to-minimal supersymmetric extension of the Standard Model with a gauge singlet superfield added to the Higgs sector [24]. In this model the lightest Higgs boson can have a weak coupling to the  $Z^0$  and would therefore be hardly visible in  $e^+e^- \rightarrow Zh^0$ . In such a model the maximum mass of the next to lightest neutral Higgs can be made to satisfy the current experimental limits with low values of  $\tan\beta$  and scalar mass  $m_0$ .

## 6 Conclusions

Detailed investigation of the dependence of the induced electric dipole moments of the electron and neutron on the SUSY breaking parameters indicates that the current experimental limits might provide useful hints toward the structure of the SUSY breaking Lagrangian. If the gaugino mass parameters are sufficiently small the squarks and sleptons might still be in the low energy region near 100 GeV and maximum SUSY CP violating phases are then still possible. The dipole moment amplitudes then suggest also a vanishing  $A$  parameter and a low  $\tan\beta$ . Critical tests of this scenario are possible at LEP II and in the next run at Fermilab. The alternative of having one or more gaugino mass parameters very large with the others small together with a small squark mass is also interesting and will be further explored in a future work.

This work was supported in part by the US Department of Energy under grant no. DE-FG02-96ER-40967 and by the "Fonds zur Förderung der Wissenschaftlichen Forschung" of Austria, project no P13139-PHY. LC wishes to thank the University of Vienna, the Institute of High Energy Physics of the Austrian Academy of Sciences, and the University of Bonn for hospitality during the period of this research. We also thank H. Eberl and S. Kraml for numerical checks of the Higgs masses.

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